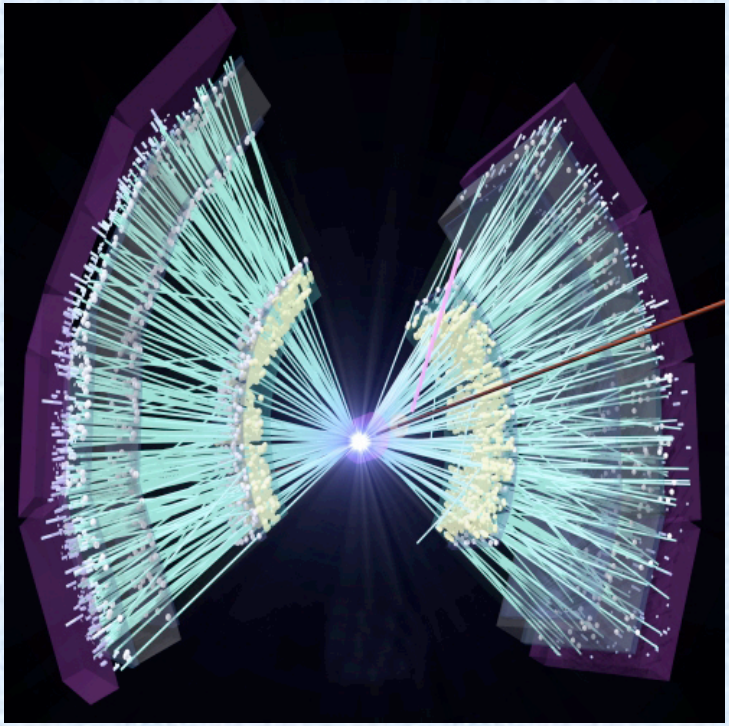
J/ψ Production in p+p and Au+Au collisions from the PHENIX Experiment



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University of Colorado

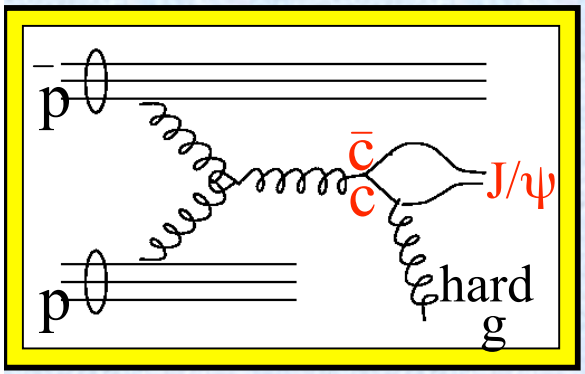
April 15, 2007

J/ψ Production

- p+p Collisions
  - Production Mechanism:

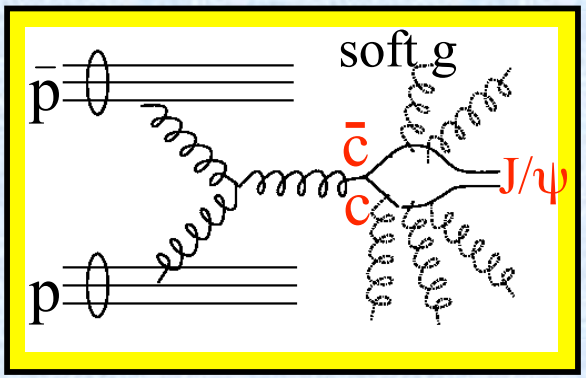
    $c\bar{c}$ pairs predominantly generated in hadronic collisions via gluonic diagrams

    Details of hadronization process remain unclear



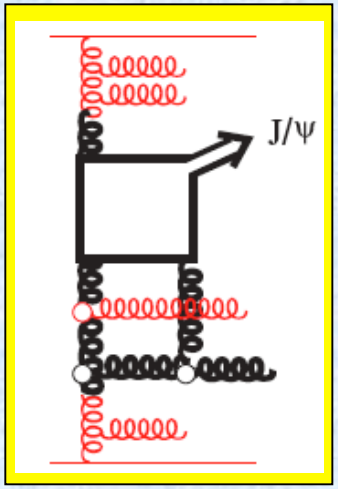
Color Singlet Model

X



Color Octet Model

X

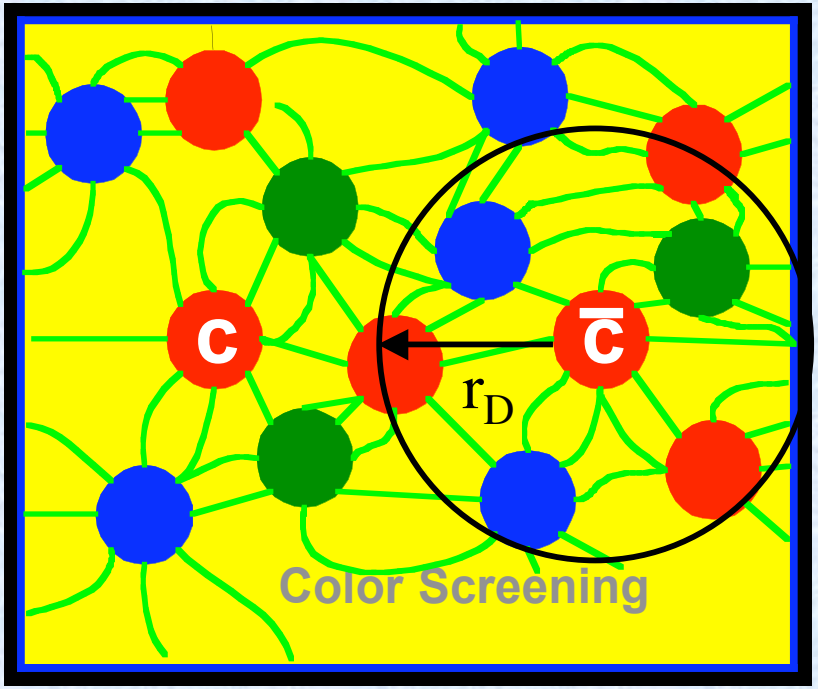


pQCD with 3-gluons

?

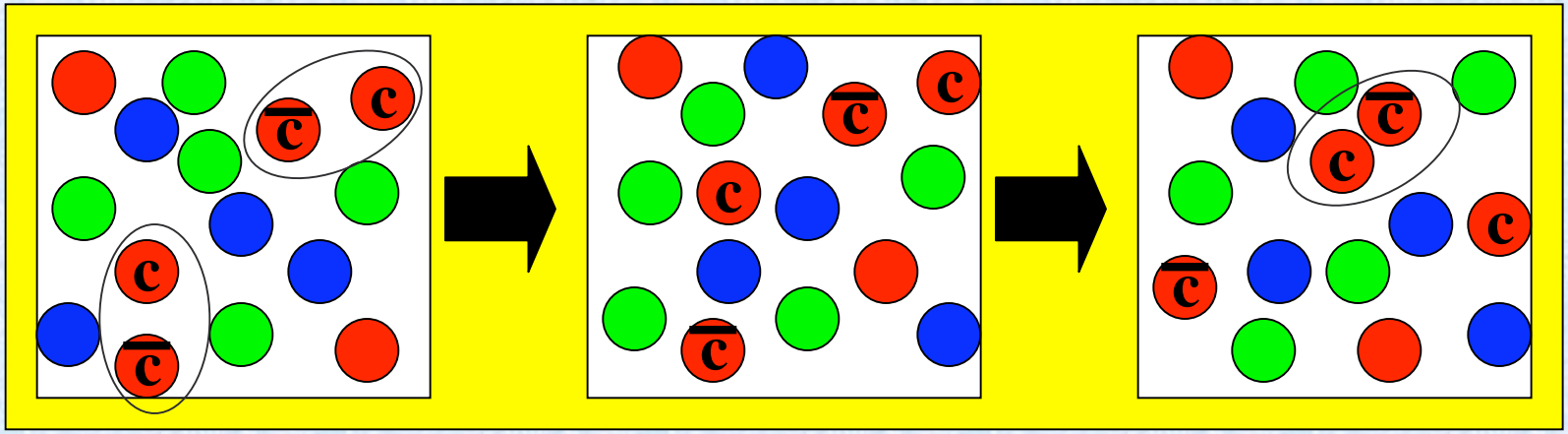
J/ψ Production

- Au+Au Collisions
  - J/ψ Suppression Models:
    - Assume quarkonia are formed only during the initial hard collisions
    - Subsequent interactions only result in additional loss of yield
    - Suppression of J/ψ yield with increasing collision centrality



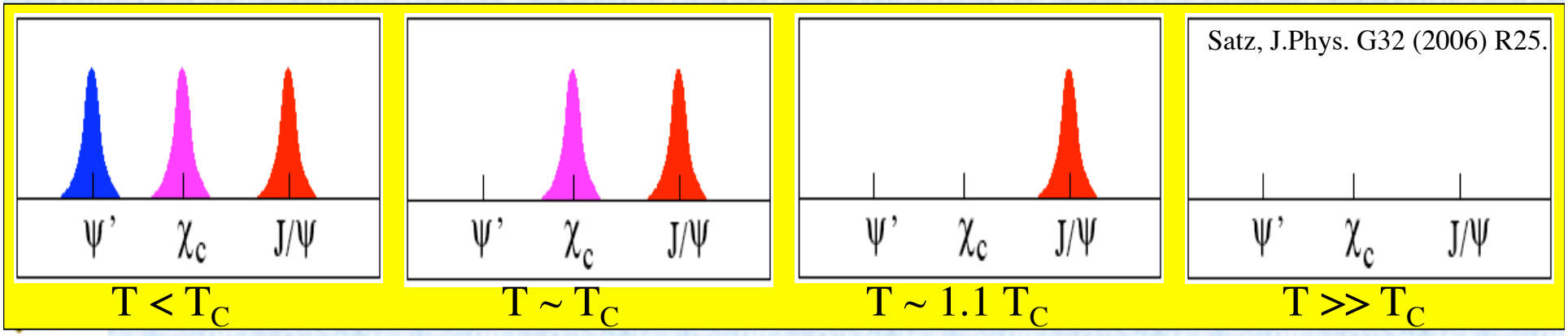
J/ψ Production

- Au+Au Collisions
  - J/ψ Suppression Models:
  - J/ψ Recombination Models:
    - In central heavy ion collisions more than one c-cbar pair is formed
    - Regeneration of J/ψ pairs from independently produced c and cbars
    - Increased J/ψ yield with increasing collision centrality
    - Narrowed J/ψ rapidity and p_T distributions with increasing centrality



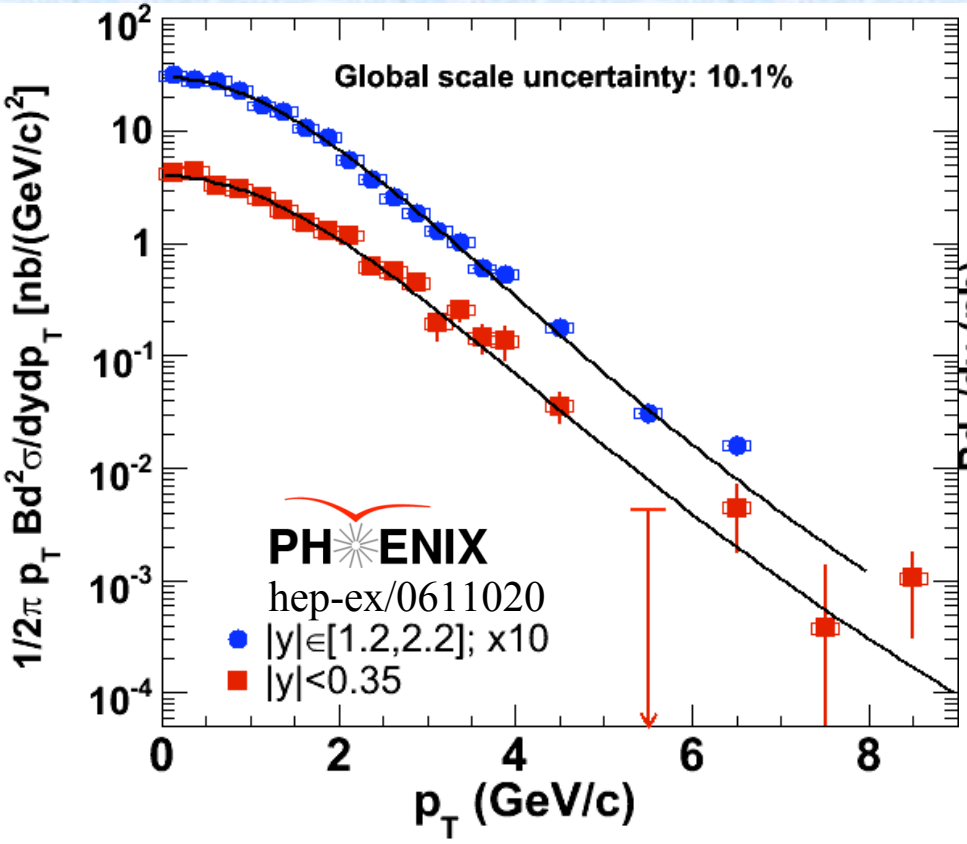
J/ψ Production

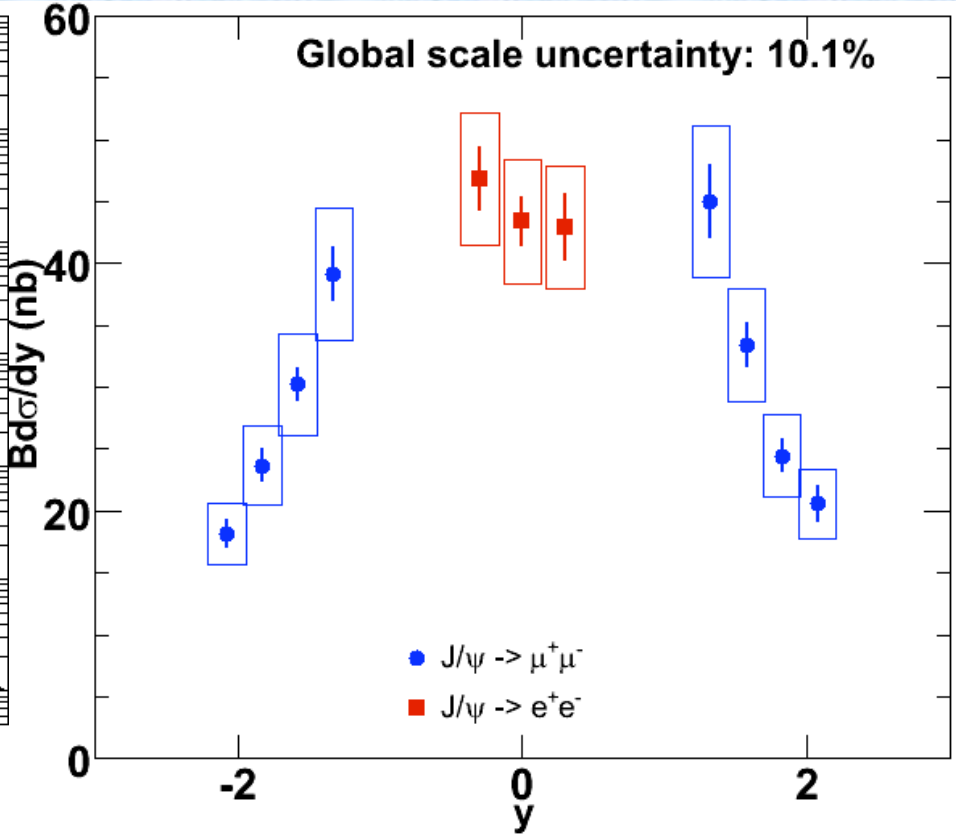
- Au+Au Collisions
  - J/ψ Suppression Models:
  - J/ψ Recombination Models:
  - Sequential Melting:
    - J/ψ yield is populated from both direct production and feeddown from the higher resonance states
    - Relative yield from each source experimentally found:
      60% direct production, 30% χ_c feeddown, 10% ψ' feeddown
    - Medium conditions determine whether each state is bound
    - Recent lattice results => J/ψ suppression turns on at $T > 2\ T_c$



p+p Collisions

J/ψ Cross Section vs p_T

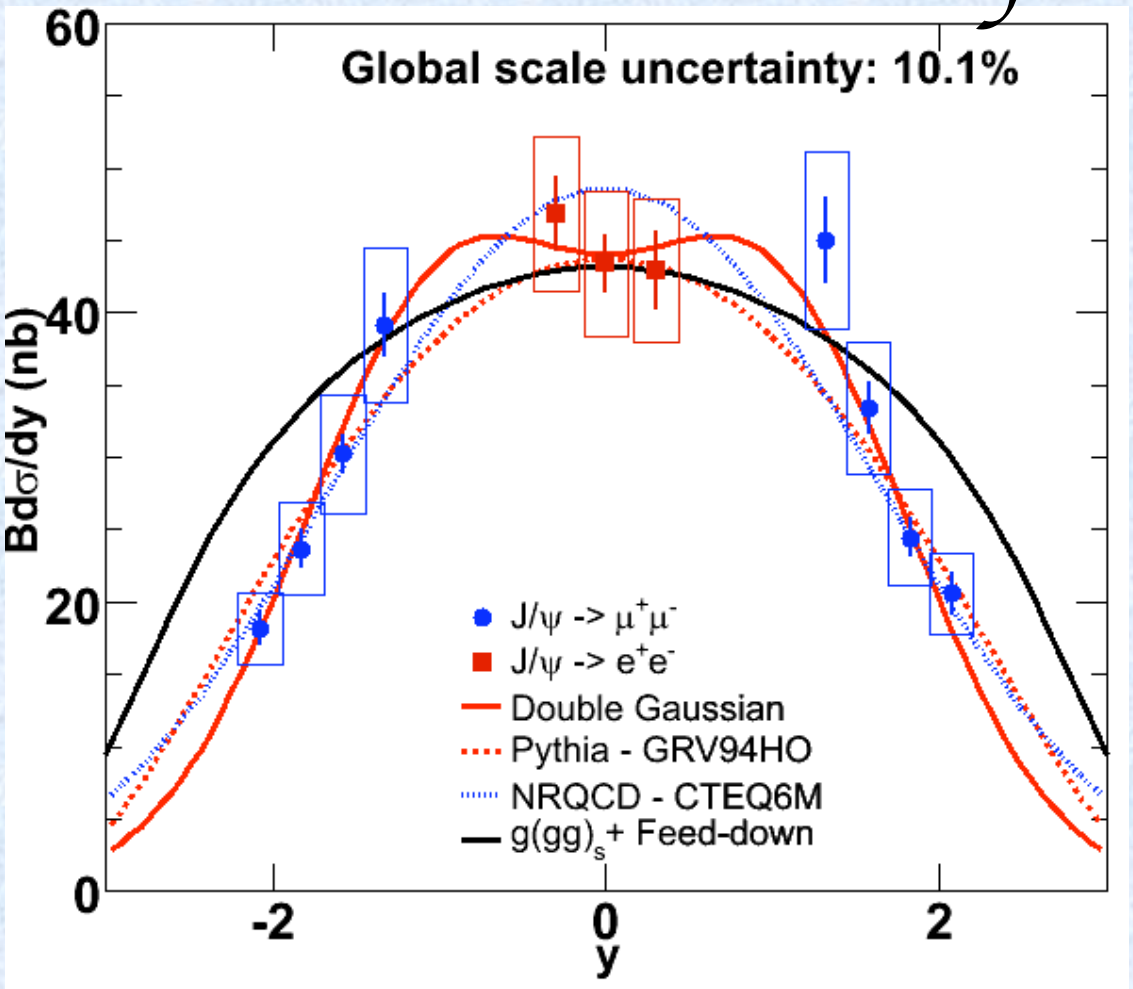




- p_T spectrum mapped from 0-9 GeV/c
- Ratio of p_T distributions shows a softening at forward rapidity

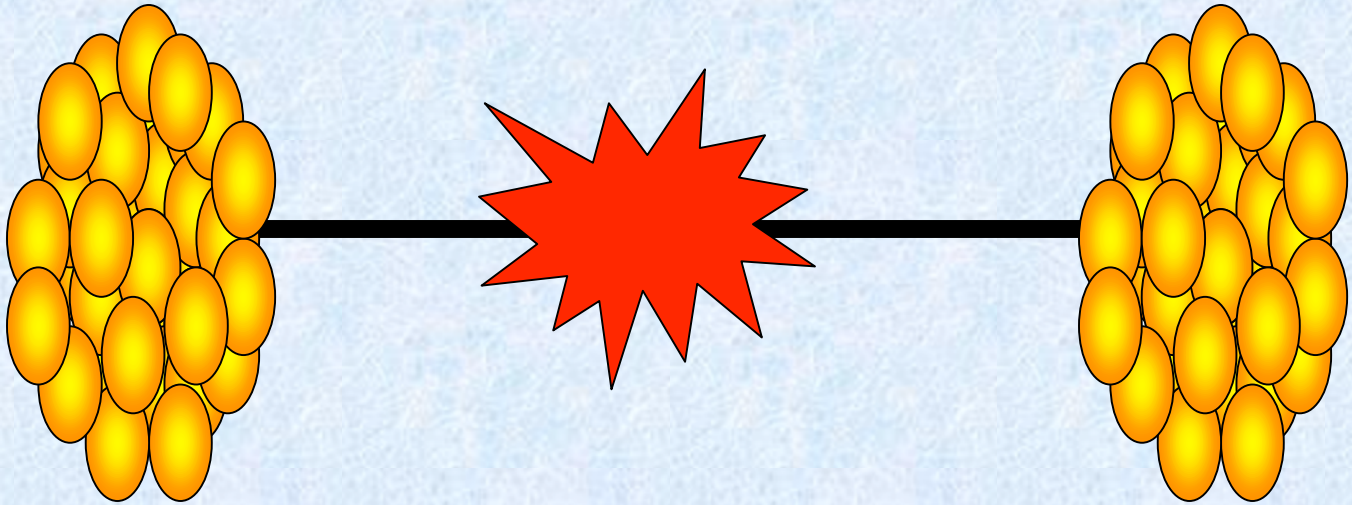
- Sufficient statistics for 11 rapidity bins
- Data now limited by systematic error

J/ψ Cross Section vs Rapidity



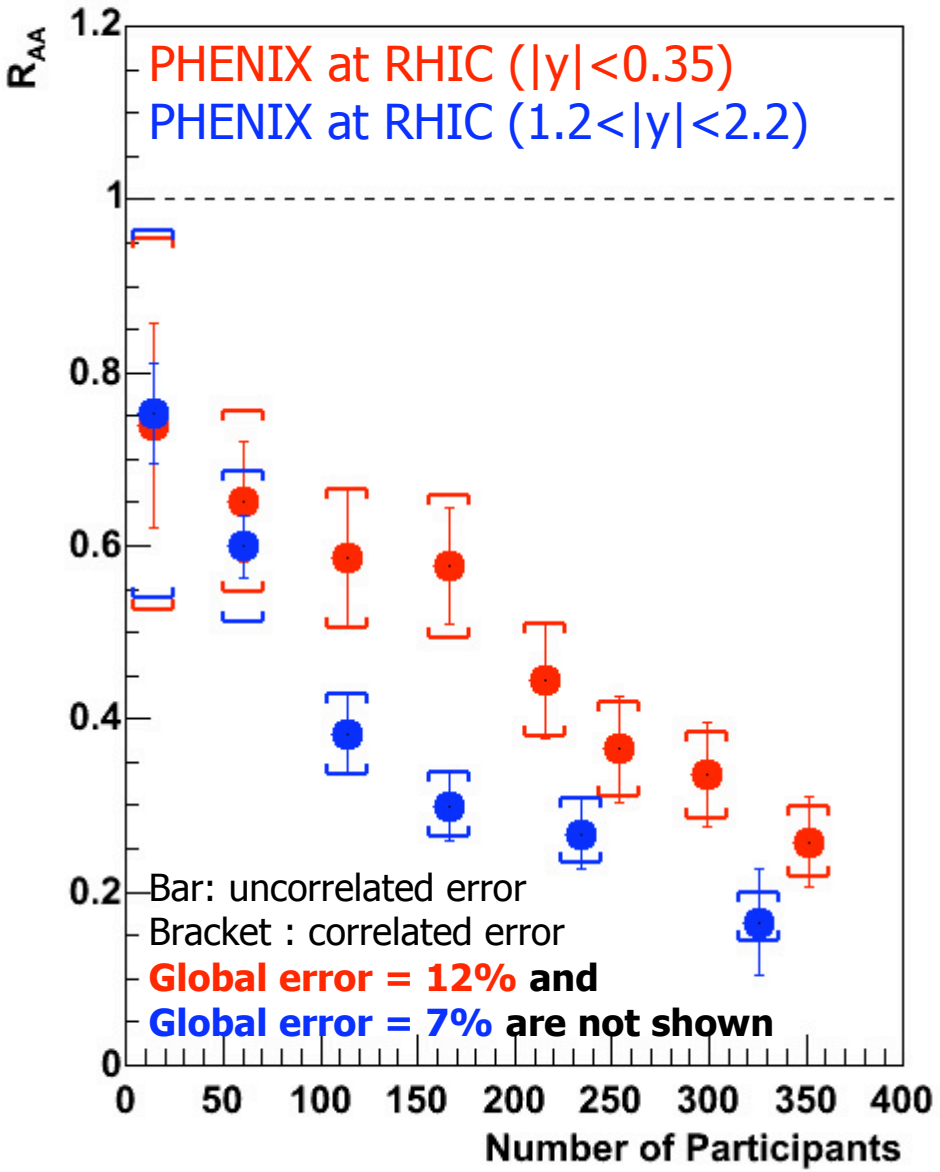
- Comparison with theory allows differentiation among the available J/ψ production mechanisms
- Many calculations are inconsistent with the steepness of the slope at forward rapidity and the slight flattening observed at mid-rapidity
- PHENIX acceptance covers 92% of integrated cross section

$$\mathbf{B_{ll} * \sigma_{pp}(J/\psi) = 178 \pm 3 \pm 53 \pm 18\ nb}$$



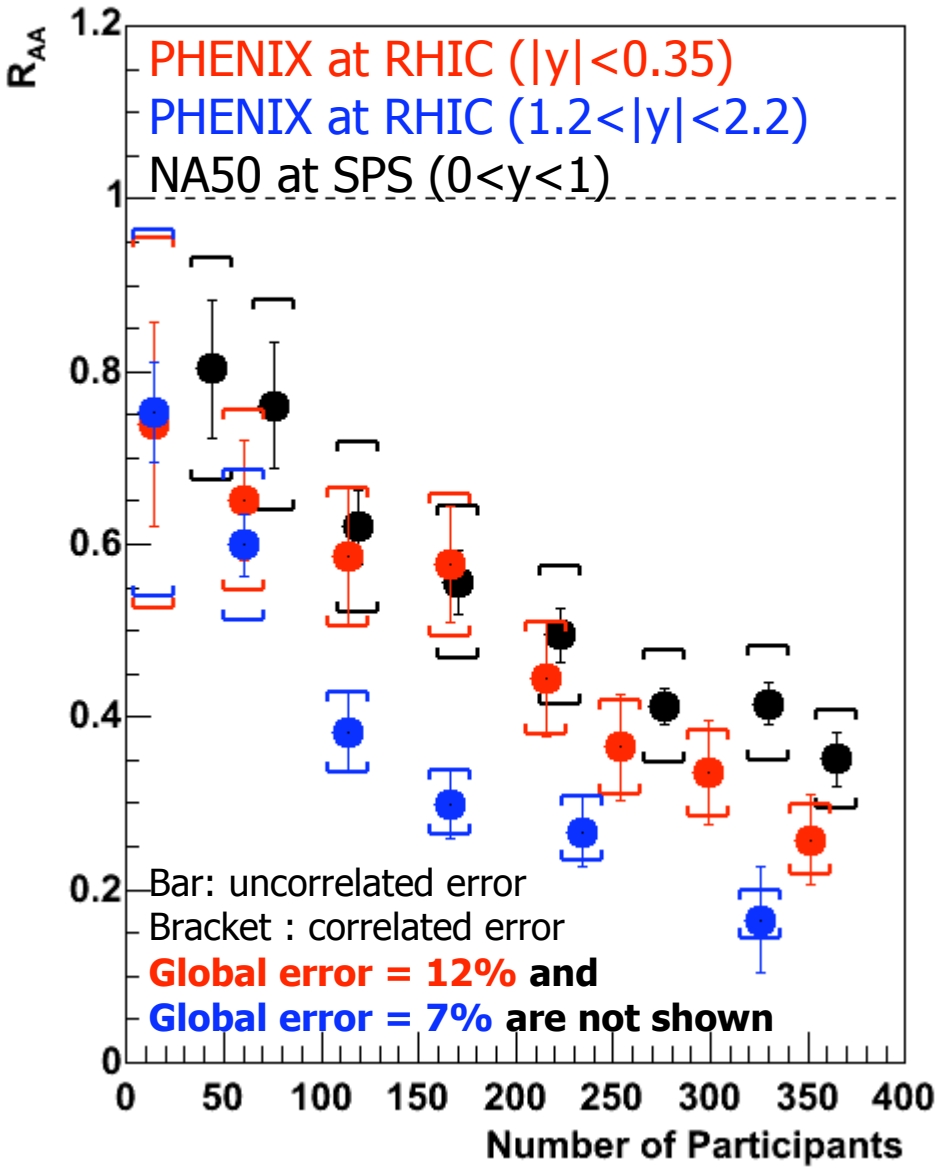
Au+Au Collisions

R_{AA} versus Centrality



- Suppression at forward rapidity greater than at mid-rapidity
- Cold nuclear matter models predict opposite trend
- Observed suppression greater than CNM predictions

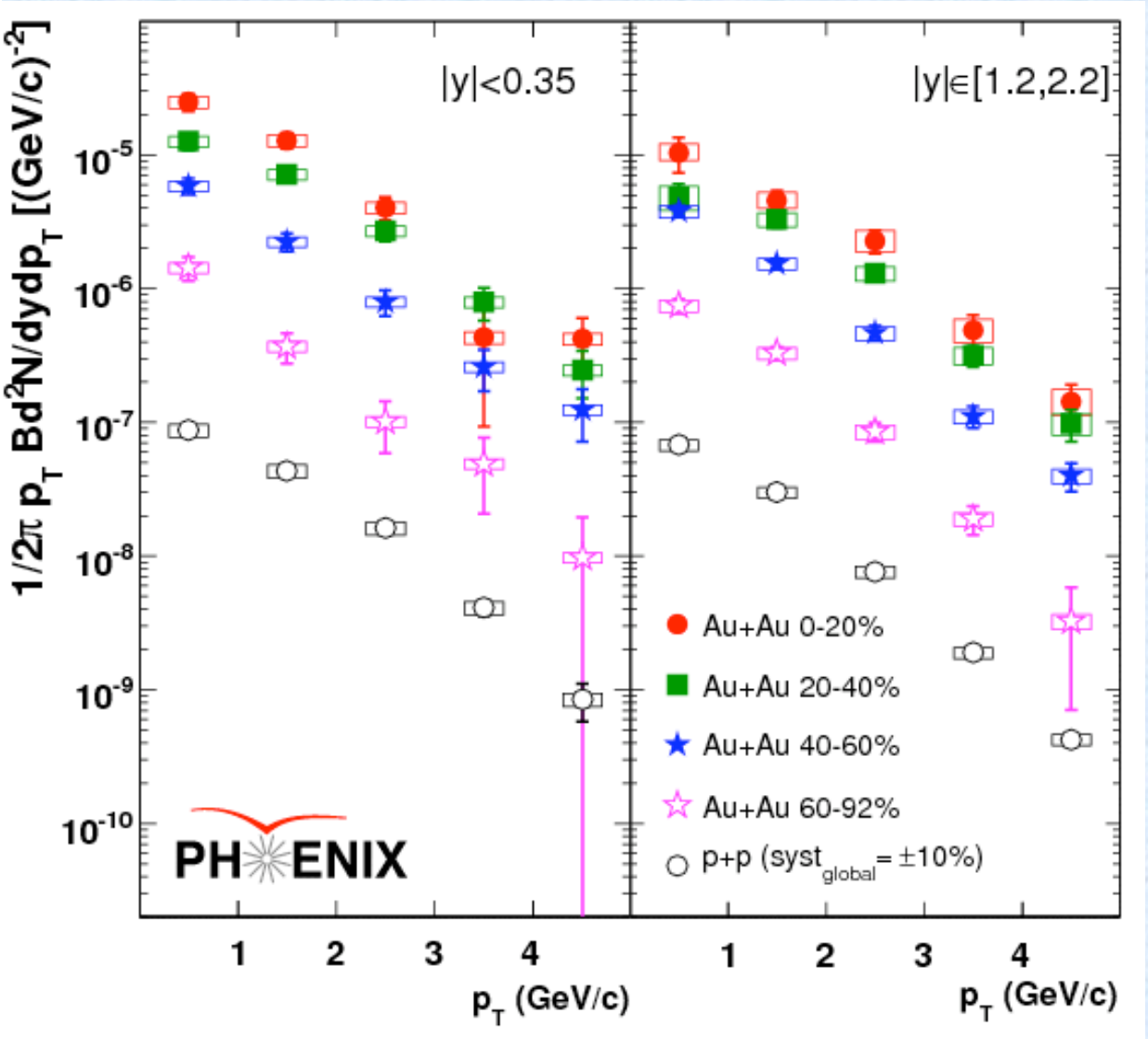
R_{AA} versus Centrality



Similar level of suppression:

- 200 GeV Au+Au @ |y|<0.35
- 158 GeV/A Pb+Pb @ 0<y<1

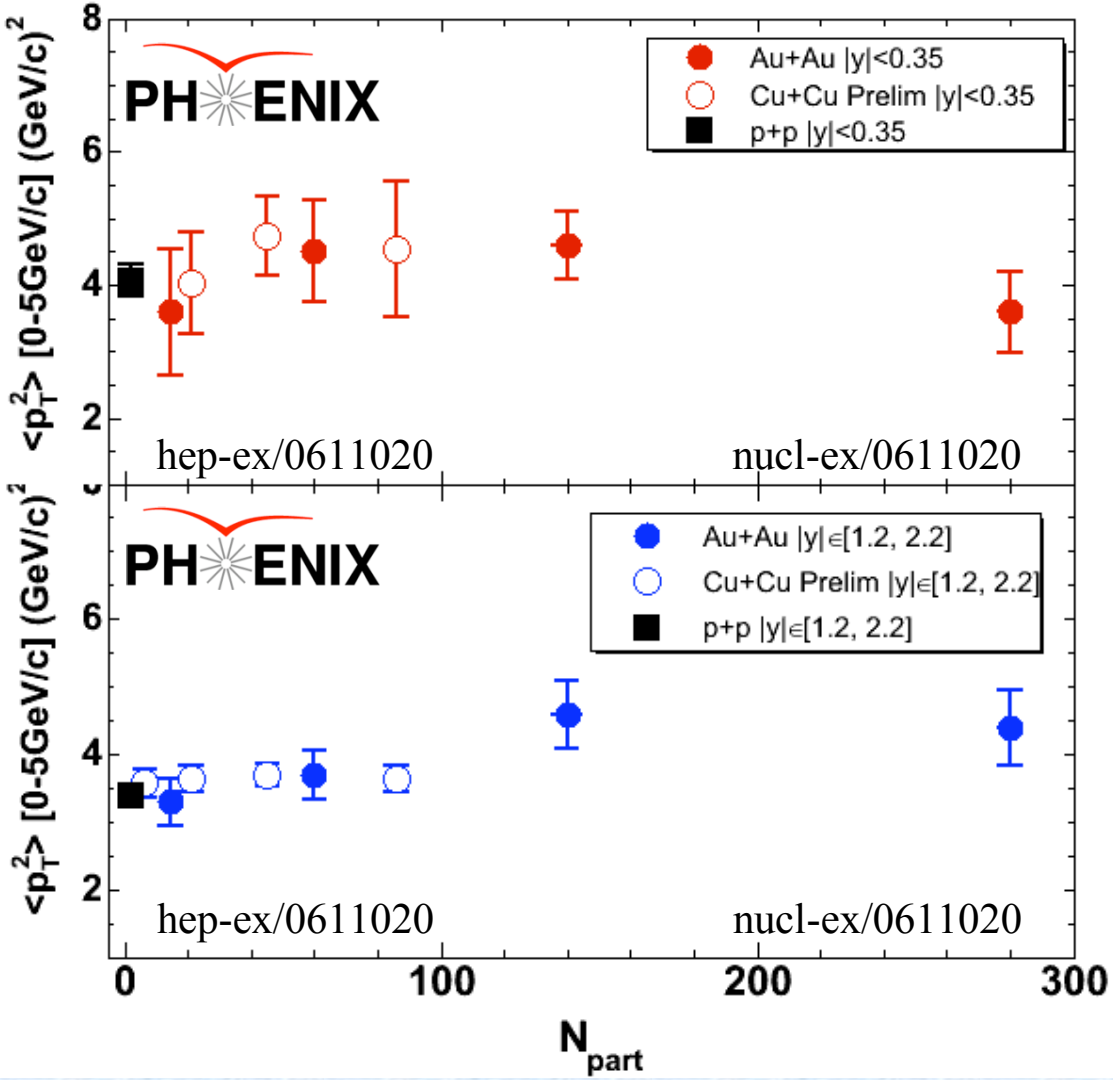
Invariant Yield versus p_T



<p_T^2> extracted using Kaplan function integrated to 5 GeV/c

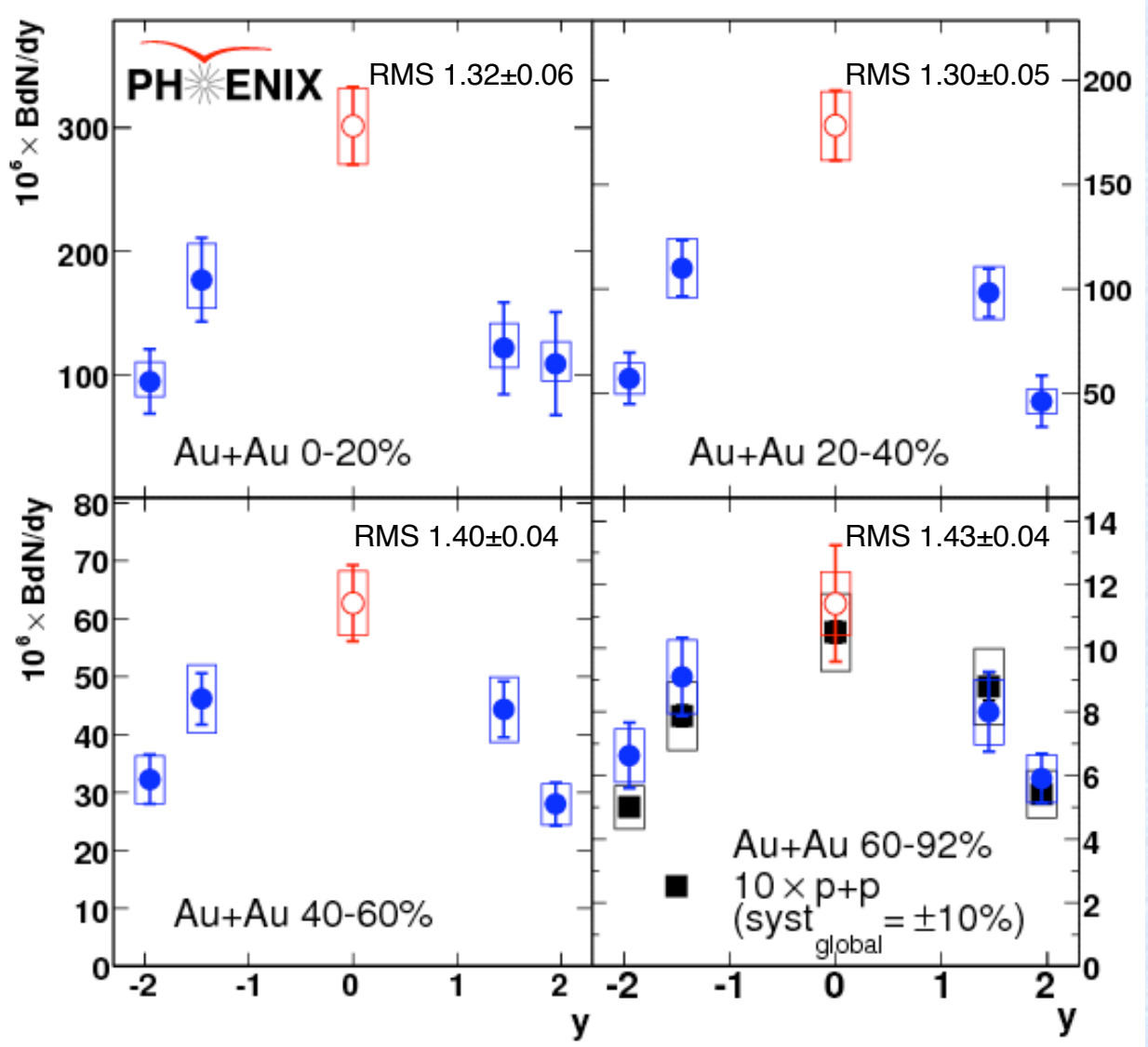
$$f(p_T) = p_0\left[1+\left(\frac{p_T}{p_1}\right)^2\right]^{-6}$$

$\langle p_T^2 \rangle$ vs Centrality



Good consistency is found between the $\langle p_T^2 \rangle$ in Heavy Ion collisions as a function of centrality and the p+p results for the $\langle p_T^2 \rangle$ integrated over $p_T < 5$GeV/c.

Invariant Yield versus Rapidity



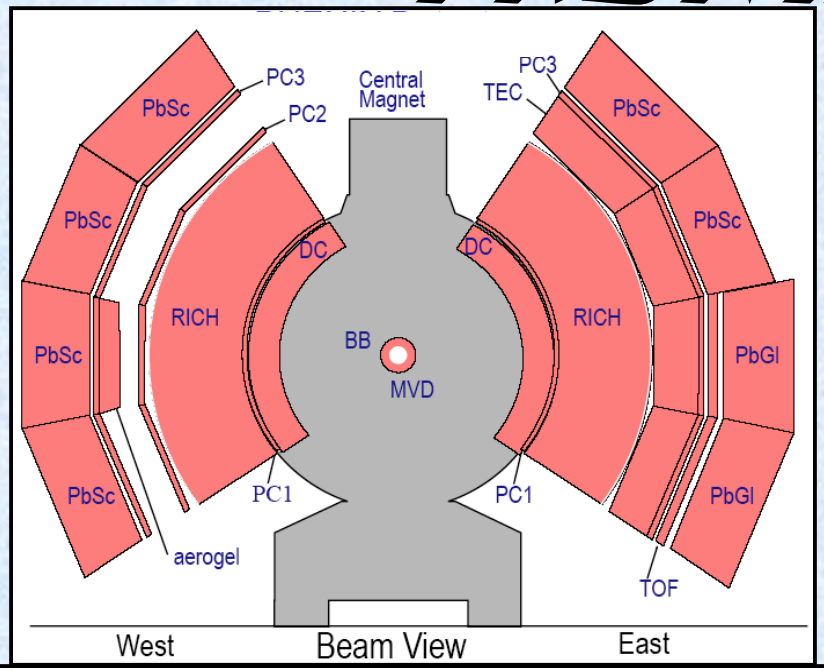
- Shape of rapidity dependence of J/ψ yield narrows slightly as a function of centrality
- No difference observed between peripheral Au+Au and p+p distributions
- Sharp rapidity narrowing predicted by recombination models not present

Summary

- p+p data:
  - Provide a challenge for production models
  - p_T spectrum mapped from 0-9 GeV/c
  - Ratio of forward and mid-rapidity p_T distributions show a softening at forward rapidity
  - Rapidity distribution slightly flatter than most models and falls off more rapidly at forward rapidity

- Au+Au data:
  - Significant J/Ψ suppression in central collisions $R_{AA} \sim 0.3$
  - Similarity between suppression observed at the SPS and RHIC is striking
  - Suppression weaker than pure color screening predictions
    - Recombination of uncorrelated quarks?
    - Sequential dissociation of charmonium states?
    - Other explanations??

PHENIX Detector

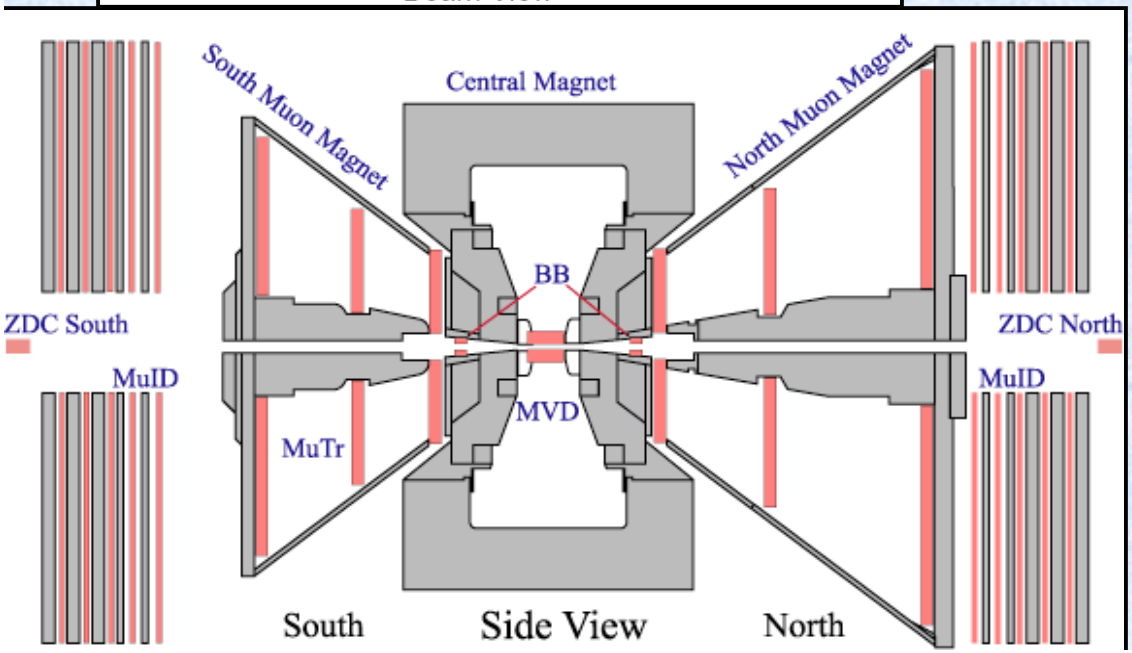


$J/\psi \rightarrow e^+ e^-$

$p > 0.2 GeV/c$

$|\eta| < 0.35$

$\Delta\phi = \pi$



$J/\psi \rightarrow \mu^+ \mu^-$

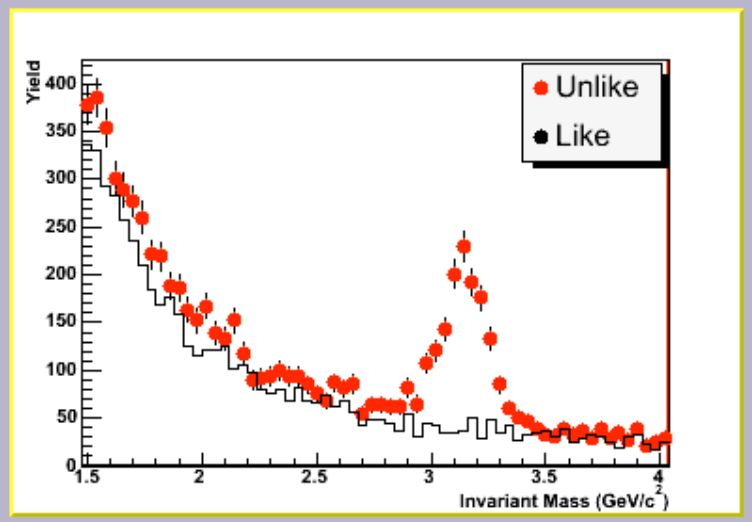
$p > 2 GeV/c$

$1.2 < |y| < 2.2$

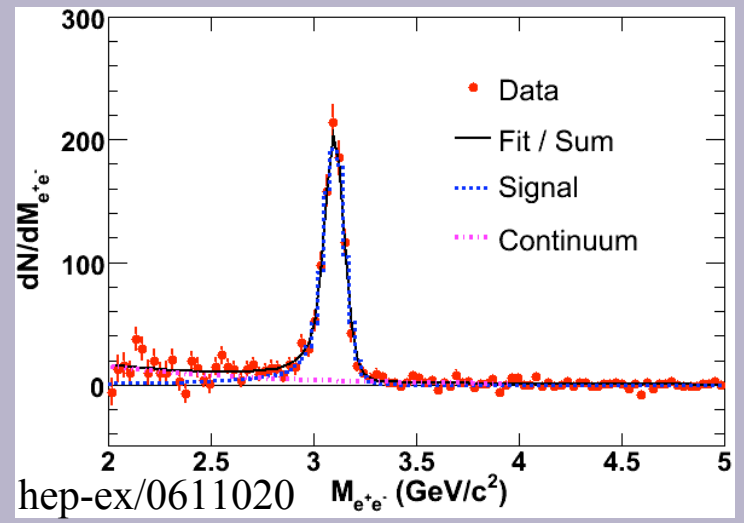
$\Delta\phi = 2\pi$

Signal Extraction

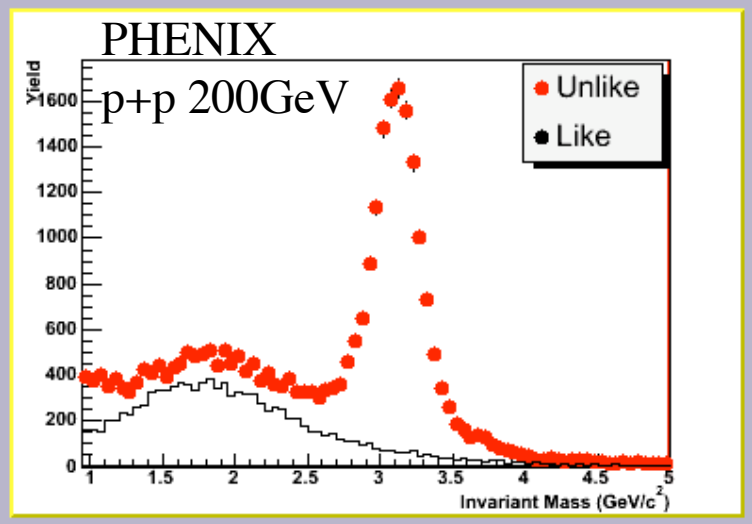
Mid-Rapidity: |y| < 0.35



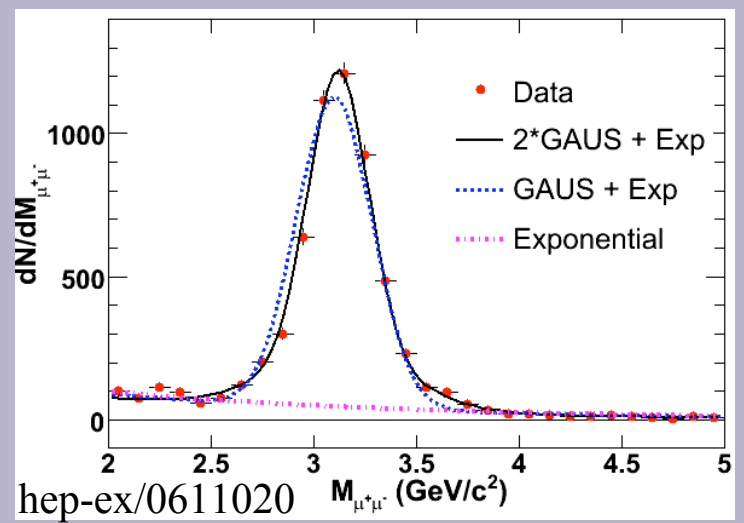
Like Sign Subtraction



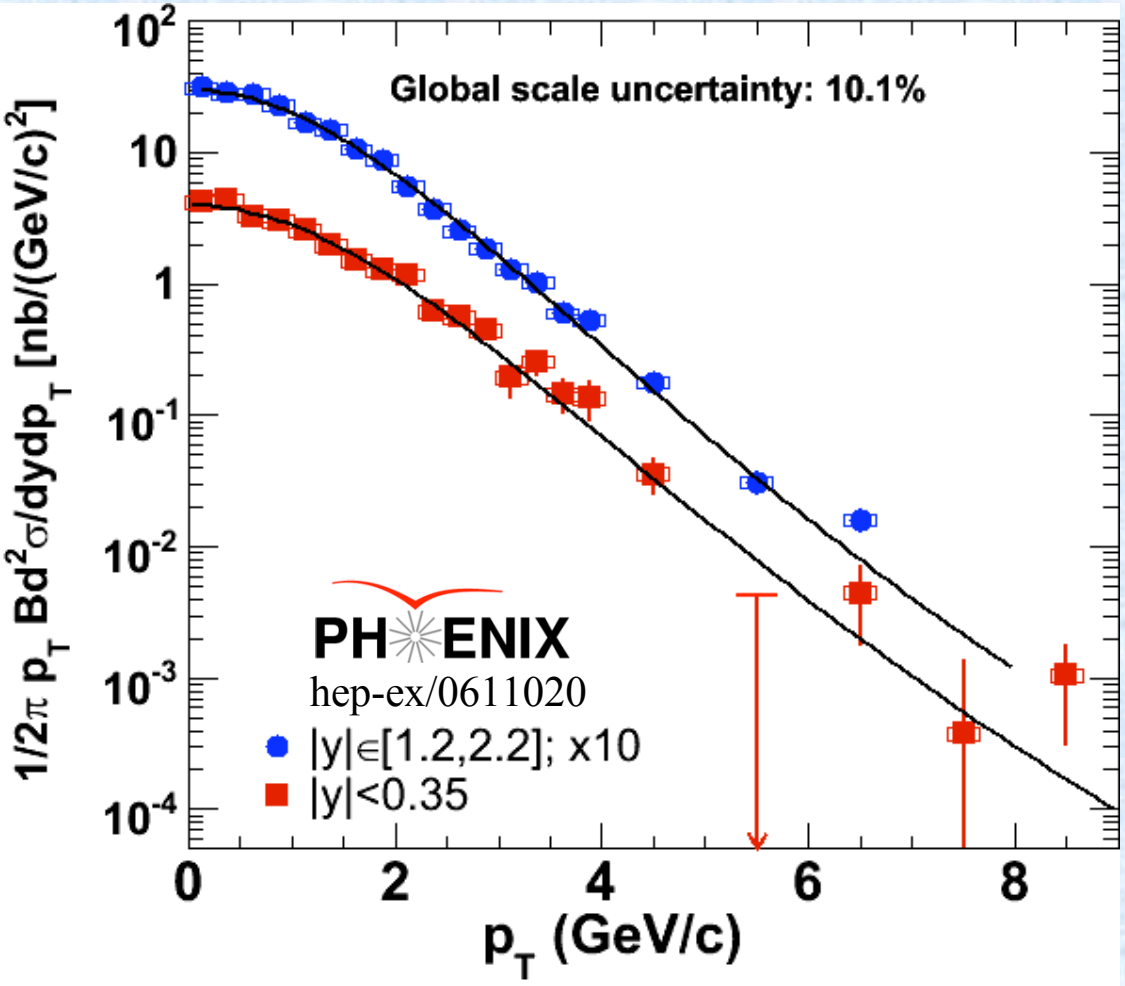
Forward Rapidity: 1.2< |y| <2.2



Event Mixed Background Subtraction



J/ψ Cross Section vs p_T



<p_T^2> extracted using Kaplan function integrated to ∞

$$f(p_T) = p_0\left[1+\left(\frac{p_T}{p_1}\right)^2\right]^{-6}$$

Mid-rapidity:

$$\left\langle p_T^2 \right\rangle = 4.14 \pm 0.18^{+0.30}_{-0.20}$$

$$\chi^2/ndf = 23/19$$

Forward rapidity:

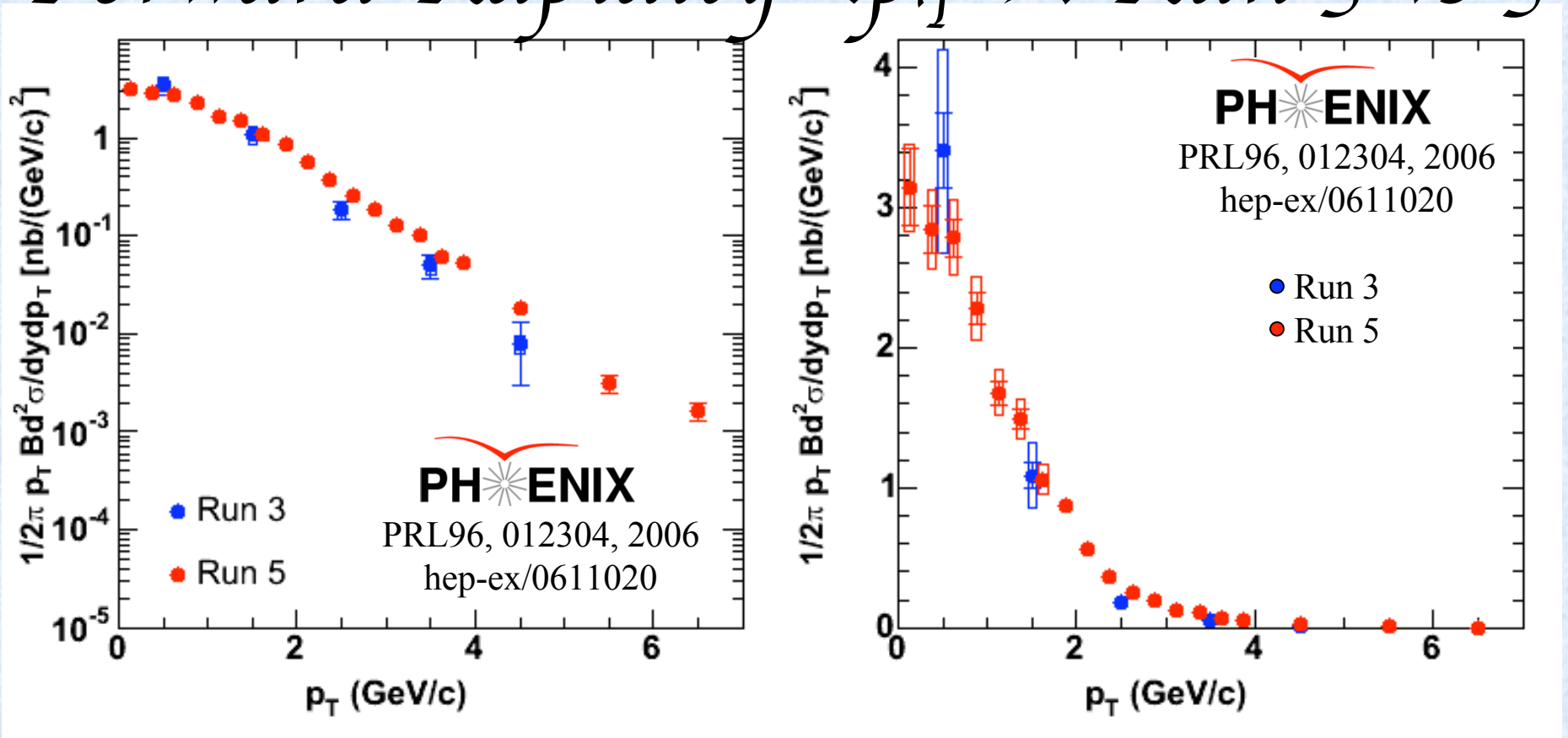
$$\left\langle p_T^2 \right\rangle = 3.59 \pm 0.06 \pm 0.16$$

$$\chi^2/ndf = 28/17$$

If the exponent is allowed to float a slightly better fit is obtained, χ^2/ndf = 20/16

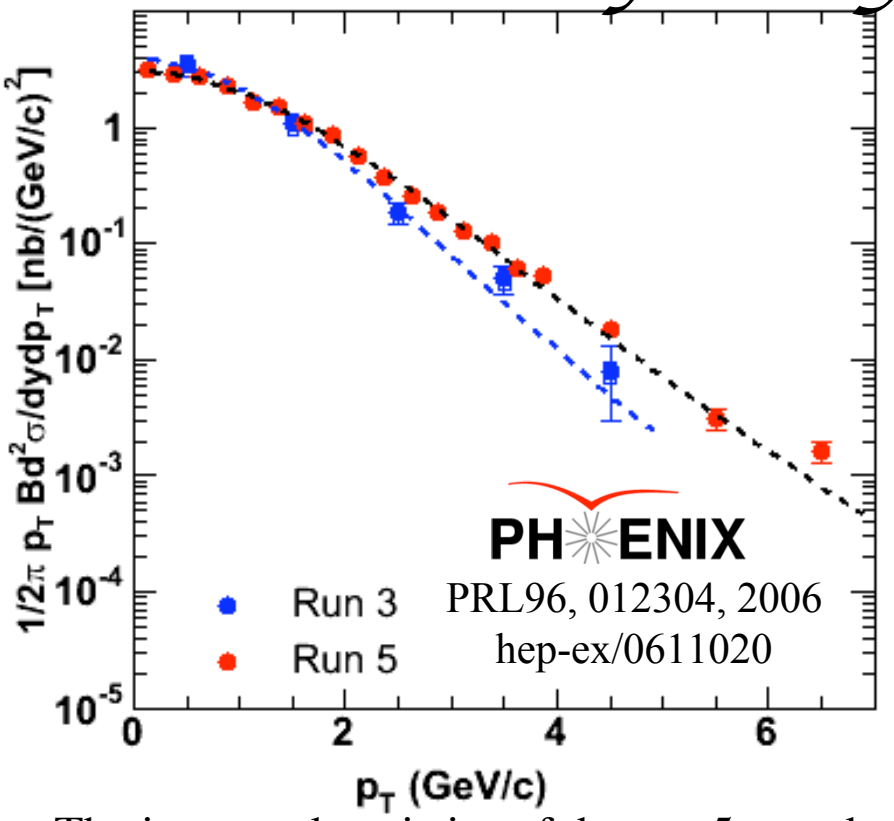
But the <p_T^2> is not significantly modified: <p_T^2> = 3.68

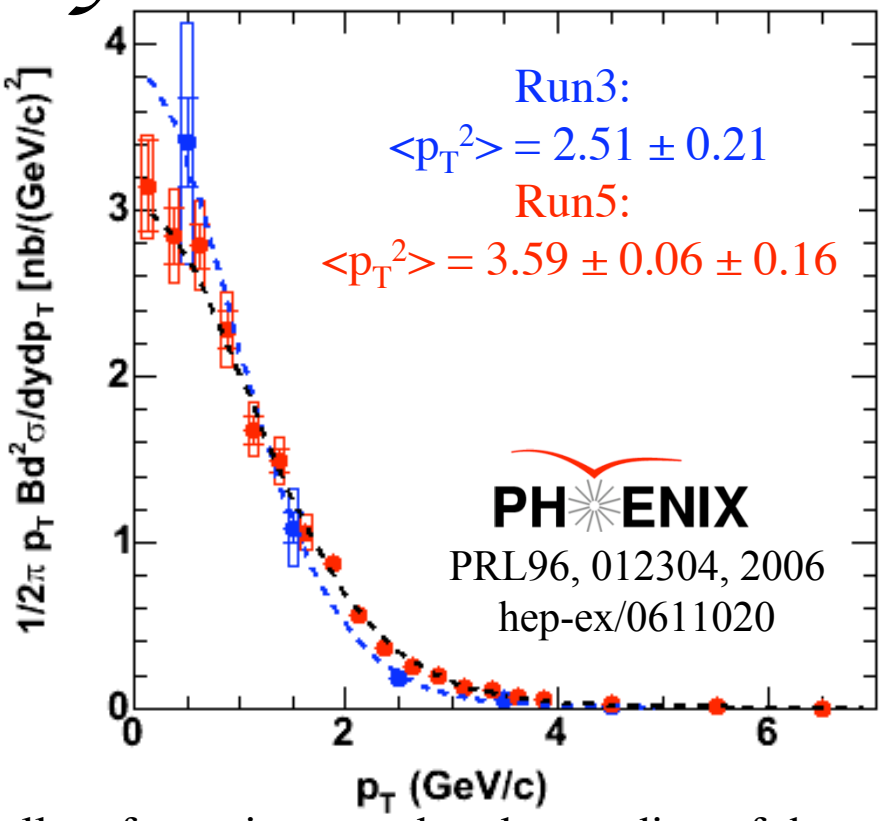
Forward Rapidity $\langle p_T^2 \rangle$: Run 3 vs 5



- x10 higher statistics available from run 5 data set relative to run 3
- Allows shape of p_T spectrum to be mapped with high precision
- Within errors the p_T spectra for both runs agree

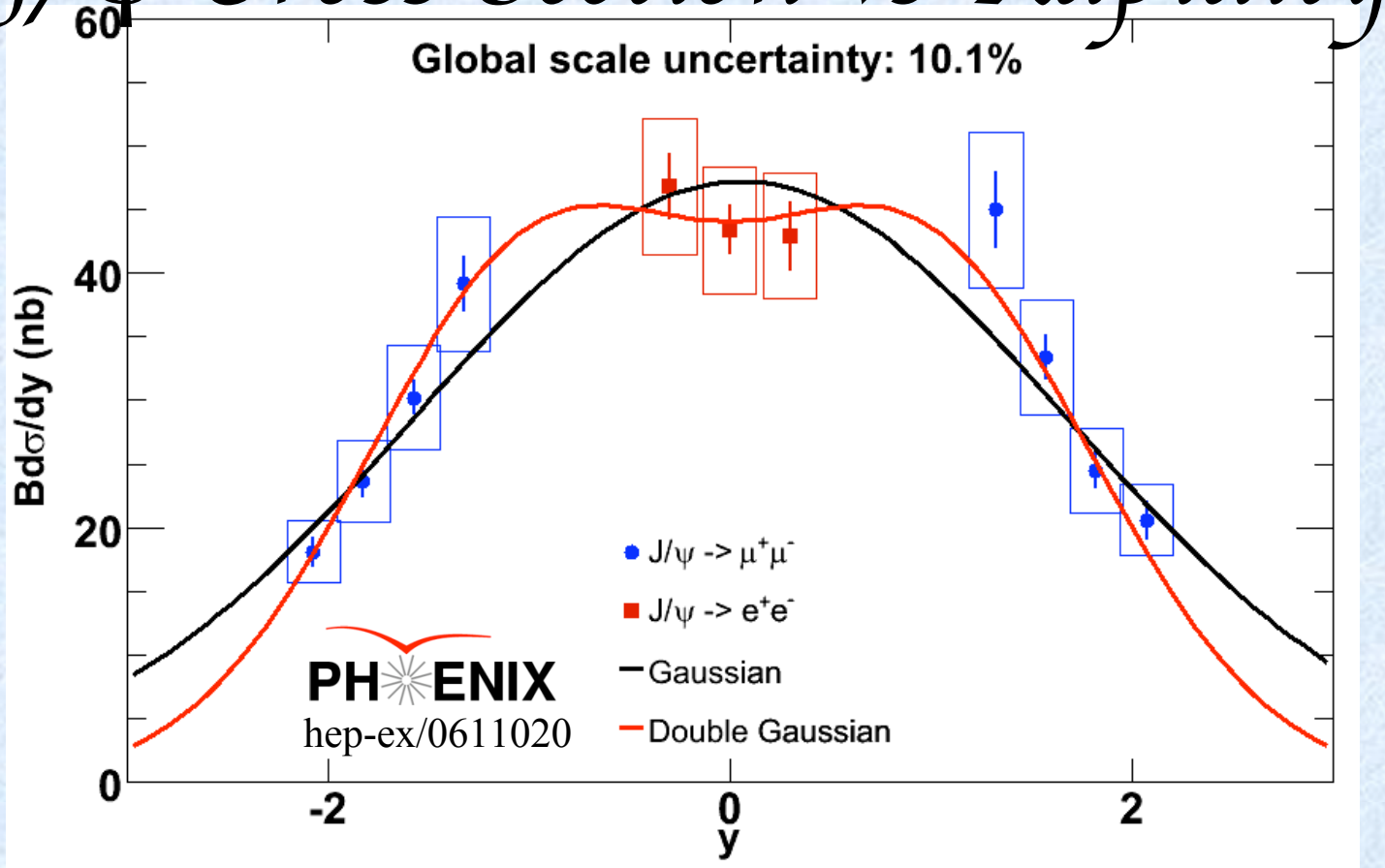
Forward Rapidity $\langle p_T^2 \rangle$: Run 3 vs 5





- The increased statistics of the run 5 p+p data allow for an improved understanding of the shape of the p_T spectrum & allow the $\langle p_T^2 \rangle$ to be completely defined ⇒ extrapolation in no longer necessary
- The run 3 p+p results have been revisited and it was found that the systematic error was underestimated.
- A reanalysis of the d+Au is underway to determine how this effects our interpretation of that data set.

J/ψ Cross Section vs Rapidity



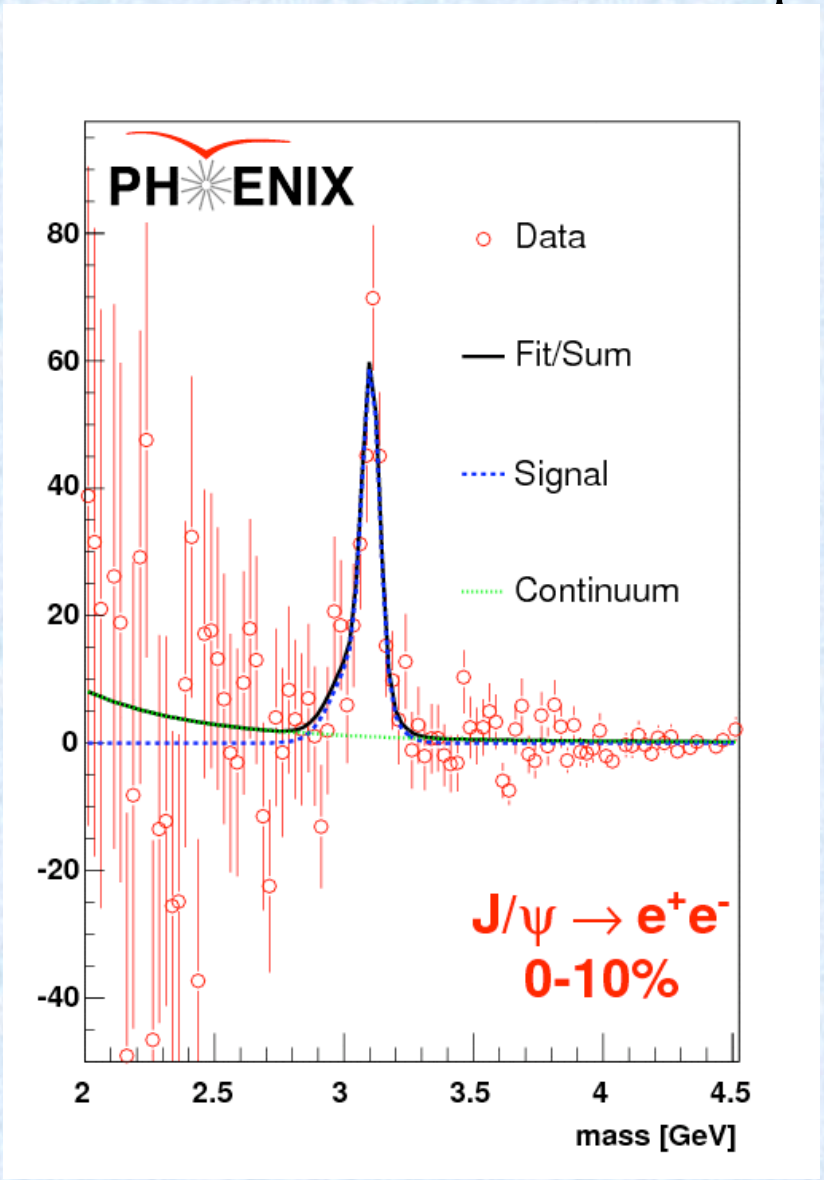
- The statistics available are large enough to allow eleven rapidity bins!!
- Data now limited by systematic error not statistics
- The data slightly favor a flat distribution over the rapidity range |y|<1.5

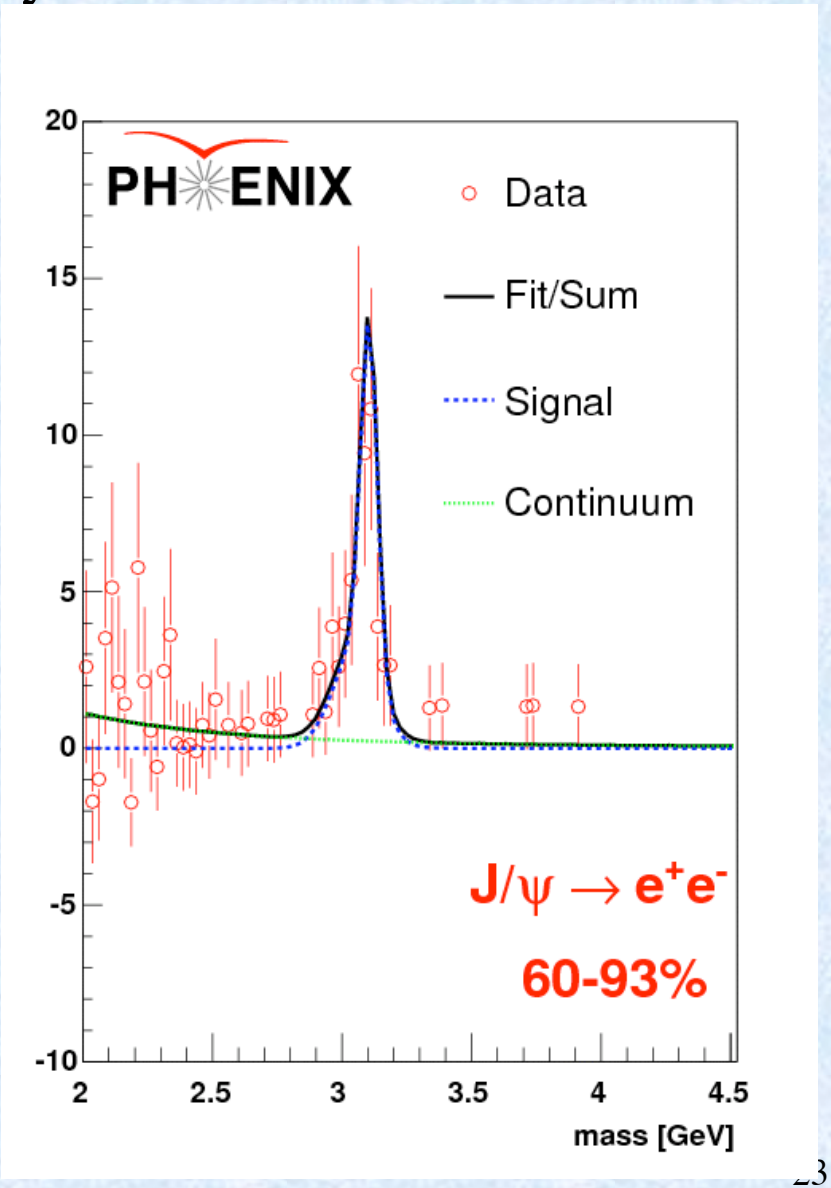
But!

- Remember the systematic errors on the mid and forward rapidity points are independent ∴ a narrower distribution is not excluded.

Signal Extraction

Mid-Rapidity: |y| < 0.35





Signal Extraction

Forward Rapidity: 1.2 < |y| < 2.2